BAR-CODE READER

BACKGROUND OF THE INVENTION

1) Field of the Invention

5   The present invention relates to a bar-code reader.

2) Description of the Related Art

   In the field of products distribution, a bar-code system is a known system. In this bar-code system, a bar code is provided to a

10 product in advance and when the product is held up to a bar-code reader (bar-code scanner), the bar code of the product is read. By reading the bar code of a product, information of a product such as product price, product name etc. is recorded in a register

   Concretely, in the bar-code unit, a following series of processes

15 is performed.

  (1) A light beam is irradiated on a bar code that is formed by an array of width information of black bars and white bars and light reflected from the bar code is received. An electric signal having amplitude corresponding to an optical power of the reflected light, is generated.

20 (2) From the change in the amplitude of the electric signal, boundary signals (edge signals) of boundary from a white bar to a black bar and of boundary from a black bar to white bar are extracted.

  (3) Distance between the edge signals that are extracted is measured as a bar-width counting value by using a clock that has a resolution

25 power from tens to hundreds of times of the bar width.

(4) From the counting value that is measured, the width of each bar that forms the bar code is measured and a ratio of widths of the white bars and black bars is calculated

Thus, in the conventional bar-code reader, if the light that is reflected from the bar code has sufficient optical power and has large amplitude, the ratio of widths of the white bars and the black bars can be known accurately. Due to this, the information of a product that is provided with a bar code can be recorded accurately in the register etc.

[Patent document 1]

Japanese Patent Application Laid-open Publication No. Hei10-261043.

However, taking into consideration an environment in which a bar-code reader is operated practically, the light reflected from the bar code is not always sufficient. Therefore, an error occurs in reading of white bars and black bars of the bar code.

Particularly, when each amplitude of a module point is viewed separately, in a practical environment, in most of the cases there happens to be a decrease in the amplitude. Therefore, it is difficult to make an accurate judgment of whether it is an edge '1' that changes from a black bar to a white bar, or an edge '-1' that changes from a white bar to a black bar, or a no edge area '0'.

Due to this, an efficient and accurate judgment of whether each module point is an edge that changes from a black bar to a white bar, or an edge that changes from a white bar to a black bar, or a no edge area, becomes very important. A bar-code reader in patent document 1 is

an apparatus that decodes a string like a bar code that is encoded by combining a maximum likelihood method and a critical distance decoding. However, in this case, the maximum likelihood method is employed only for decoding and not for ternarizing the amplitude of

5   each module point. Therefore, patent document 1 has not solved this problem.

SUMMARY OF THE INVENTION

It is an object of the present invention to at least solve the

10   problems in the conventional technology.

The other objects, features and advantages of the present invention are specifically set forth in or will become apparent from the following detailed descriptions of the invention when read in conjunction

15   with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 a block diagram of a configuration of a bar-code reader in this embodiment;

20   Fig. 2 illustrates examples of output data of various sections in Fig. 1;

Fig. 3 is a flow chart of a processing procedure of a reading processor in Fig. 1;

Fig. 4 is an illustration (1) of maximum likelihood judgment by

25   maximum likelihood judgment processor in Fig. 1;

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Fig. 5 is an illustration (2) of maximum likelihood judgment by maximum likelihood judgment processor in Fig. 1;

Fig. 6 is an illustration (3) of maximum likelihood judgment by maximum likelihood judgment processor in Fig. 1;

5 Fig. 7 is an illustration (1) indicating constraint of state transition;

Fig. 8 is an illustration (2) indicating constraint of state transition;

Fig. 9 is an illustration (3) indicating constraint of state

10 transition;

Fig. 10 is an illustration of path change to be performed when constraint is not fulfilled; and

Fig. 11 is an graphical representation of maximum likelihood judgment.

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DETAILED DESCRIPTION

Exemplary embodiment of a bar-code reader relating to the present invention is explained in detail below with reference to the accompanying diagrams.

20 Configuration of a bar-code reader in this embodiment is explained below. Fig. 1 is a block diagram of a configuration of the bar-code reader in this embodiment. As it is shown in Fig. 1, the bar-code reader includes an optical scanner 2, an analog processor 3, an AD converter 4, and a reading processor 5.

25 The optical scanner 2 includes an LD (laser diode) 2a and a

polygon mirror 2b.   The LD 2a emits a light beam and the polygon

mirror 2b is formed by a mirror that reflects the light beam that is

emitted from the LD 2a.   The direction of reflection of the light beam is

changed by rotation of the polygon mirror 2b by a motor that is not

5   shown in the diagram.   Thus, the polygon mirror 2b provides a plurality

of scanning patterns.   By using the optical scanner 2, the light beam

that is emitted from the LD 2a, is radiated on a bar code 1 that is held

on a reading surface due to the rotation of the polygon mirror 2b.   The

light beam is irradiated in a direction from a to b in the diagram.

10   A light receiving section of the analog processor 3 receives light

that includes light that is reflected upon irradiating the bar code 1.   The

analog processor 3 performs opto-electric conversion of the light

received and converts it to an electric signal that has an amplitude

according to the intensity of the light and amplifies the signal according

15   to the requirement.   The AD converter 4 performs digital sampling of

the analog signal that has undergone opto-electric conversion and the

output from the analog processor 3, and outputs it as a digital signal.

        The reading processor 5 specifies bar-code characters based on

the digital signal that is received from the AD converter 4 and outputs it.

20   The reading processor 5 includes an extractor 5a, a narrow-band

differential processor 5b, a module-frequency extractor 5c, a

module-point extractor 5d, a module-timing extractor 5e, a maximum

likelihood judgment processor 5f, and a bar-code demodulator 5g.

        The extractor 5a extracts only a signal that is apparently a bar

25.   code from the signal that is subjected to opto-electric conversion to

reduce the load of processing in the latter part.   Concretely, the signal

that is subjected to opto-electric conversion is in the form of a wave

with time on the vertical axis and amplitude on the horizontal axis.

Therefore, the extractor 5a extracts a part of the waveform as shown in

5   Fig. 2(a).

The module-frequency extractor 5c extracts frequency that is

equivalent to a basic module of a bar code signal.   The narrow-band

differential processor 5b performs the narrow-band differentiation of the

signal that is subjected to opto-electric conversion based on the

10   frequency equivalent to the basic module that is extracted by the

module-frequency extractor 5c.   Therefore, the narrow-band differential

processor 5b extracts a wave form of an edge as shown in Fig. 2(b).

Concretely, when a black bar in the bar code 1 is changed to a white

bar, a plus (positive) edge is developed and when a white bar in the bar

15   code 1 is changed to a black bar, a minus (negative) edge is developed.

The module-timing extractor 5e extracts a timing for the

extraction of a module point, based on the frequency that is equivalent

to the basic module that is extracted by the module-frequency extractor

5c.   The module-point extractor 5d extracts a module point according

20   to the timing that is extracted by the module-timing extractor 5e as

shown in Fig. 2(c).

The maximum likelihood judgment processor 5f is a

characteristic processor of the present invention and assigns the states

1, 0, and -1 that have predetermined reference value in a plurality of

25   continuous module points respectively.   The maximum likelihood

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judgment processor 5f also assigns a least squared error of the amplitude of a module that is to be linked to a path that connects each module point as a path metric. The maximum likelihood judgment processor 5f ternarizes the state of a module point that is at the origin

5   of the path linkage of the survival path, taking a path for which the sum of path metrics that have gone through predetermined path, becomes the least (minimum) as a survival path.

The reason for making the maximum likelihood judgment is as follows. When each amplitude of a module point is viewed separately,

10   in the practical environment, in most of the cases there happens to be a decrease in the amplitude. Therefore, it is difficult to make an accurate judgment of whether it is an edge '1' that changes from a black bar to a white bar, or an edge '-1' that changes from a white bar to a black bar, or a no edge area '0'. In other words, in the maximum

15   likelihood judgment processor, a ternary judgment of each module is performed according to a transition state between a plurality of module points rather than viewing a module point locally.

In this case, the maximum likelihood judgment processor 5f is also characterized by a point that imposes restriction on a path

20   according to the differential characteristics. Concretely, a path from the state 1 to the state 1, a path form the state -1 to the state -1, a path from the state 1 to the state 1 via desired number of states 0, and a path from the state -1 to the state -1 via desired number of states 0 are inhibited. This is because, although a state transition from the state 1

25   to the state 1 implies that there exists an edge from a black bar to a

black bar, in a case of bar code, the black bar not being a multivalue, this transition does not occur. In other words, there can be no shift except either from the state 1 to the state 0 or from the state 1 to the state -1. Due to the similar reason, the path from the state -1 to the

5   state -1, a path from the state 1 to the state 1 via desired number of states 0, and a path from the state -1 to the state -1 via desired number of states 0 are inhibited.

Moreover, if a path from the state 1 to the state 0 or a path from the state -1 to the state 0 exists, the maximum likelihood judgment

10   processor 5f leaves a path from the state 0 to the state 0. The reason for leaving the path from the state 0 to the state 0 is as follows. For example, when only the path undergoing transition from the state -1 to the state -1 via the state 0 exists, obviously the metric value is inappropriate. Therefore, a transition from the state 0 to the state 0

15   has to be left as a candidate.

Furthermore, although the maximum likelihood judgment processor 5f makes the least squared error of the amplitude of a module that is to be linked and the reference respectively, as a path metric, when there is a thick black bar and a thick white bar, the

20   reference value is caused to change. The reason to perform this process is that the amplitude of a module point decreases due to a thick black bar or a thick white bar, resulting in an error in the survival path. This is explained in detail in the latter part.

The bar-code demodulator 5g specifies the combination of black

25   bars and white bars that forms the bar code 1 and outputs bar-code

characters corresponding to the specified data.

Following is the description of a processing procedure of the reading processor 5. Fig. 3 is a flow chart of the processing procedure of the reading processor 5. As it is shown in Fig. 3, in the reading

5 processor 5, the extractor 5a extracts a part that is apparently a bar-code signal from the signal that is subjected to opto-electric conversion (step S101)

Then, the narrow-band differential processor 5b differentiates using the module frequency that is extracted by the module-frequency

10 extractor 5c and extracts a wave form of an edge from a waveform of a part that is apparently the bar-code signal (step S102). Moreover, the module-point extractor 5d extracts a module point from a waveform of an edge by using the module-timing that is extracted by the module-timing extractor 5e using the module frequency (step S103).

15 Thus, upon the extraction of the module-point from the waveform of the edge, the maximum likelihood judgment processor 5f performs the ternary judgment by using the maximum likelihood method (step S104). Concretely, the maximum likelihood judgment processor 5f assigns the state 1, the state 0, and the state -1 that has a

20 predetermined reference value to a plurality of module points respectively. The maximum likelihood judgment processor 5f provides a least squared error of the amplitude of a module that is to be linked and the reference, to a path that connects all the module points, as a path metric. Further, the maximum likelihood judgment processor 5f

25 ternarizes the state of a module point that is at the origin of the path

linkage of the survival path, taking a path for which the sum of path metrics that have undergone the predetermined path becomes the least (minimum) as a survival path.

Then, the bar-code demodulator 5i demodulates the bar-code characters that imply black bars and white bars of the bar code 1, by using the result of ternarizing by the maximum likelihood judgment processor 5f (step S105).

Further, the processing by the maximum likelihood judgment processor 5f that is shown in Fig. 1 is described concretely by using the diagrams from Fig. 4 to Fig. 6. As it is shown in Fig. 4, a certain module point is associated with time t, the subsequent module point in continuation with the module point is associated with time t+1, and the states 1, the state 0, and the state -1 are assigned respectively. Paths to each state from time t and time t+1 are taken into consideration. As already been described earlier, since the transitions from the state 1 to the state 1 and from the state -1 to the state -1 are not allowed, paths corresponding to these transitions are not developed.

Then, a path metric is assigned to each path. Here, a squared error between the amplitude of the module point of time t+1 and (reference that is assigned to) each state is assigned as a path metric. In this case, since the references of the state 1, the state 0, and the state -1 are '1', '0', and '-1' respectively and the amplitude of the module point of time t+1 is 0.2, the path metric of the path from the state 0 to the state 1 is $(1-0.02)^2=0.64$. The metric for a path of each state is assigned in a similar manner.

Further, the state transition from time t+1 to time t+2 as shown in Fig. 4(b) is taken into consideration. An unnecessary path from time t to time t+1 is deleted at this stage. Concretely, the path from the state 0 to the state 1 is left, but the path from the state -1 to the state 1 is deleted. In other words, among the paths to the same state 1, only those paths for which the path metric becomes small are left and the remaining paths are deleted. The reason for leaving the paths for which the path metric becomes small is that the small path metric implies that there is more possibility of leading to a path that has a small squared error.

Further, a path and a path metric are calculated (computed) by taking into consideration the state transition from time t+1 to time t+2 similarly as for the state transition from time t to time t+1. For a path from state t+1 to t+2, a path metric of a path that shifts to the previous state is added. The reason for this is that, finally, the state of time t is determined by using the smallest survival path of the path metric.

Further, after calculating (computing) a path and a path metric from time t+2 to time t+3 as shown in Fig. 5(a), a path and a path metric from time t+3 to time t+4 are calculated as shown in Fig. 5(b). In this case, there is not need to provide a path from the state 0 to the state 1 among the paths from time t+3 to time t+4. This is because, a path to the state 0 of time t+3 from the state 1 of time t+2 is survived and it becomes a path that shifts from the state 1 to the state 1 via the state 0 which is an inhibited condition.

As it is shown in Fig. 6, upon calculating the path metric for

each path at time t+4, the path metric (leading) to the state 1 becomes 0.18, the path metric (leading) to the state 0 becomes 0.58, and the path metric (leading) to the state -1 becomes 3.78. From this, the path metric 0.18 (leading) to the state 1 becomes a metric having a minimum

5   value.

If the time to go back (to trace back) that is determined in advance is 4, four paths are traced back from the state 1. This enables to go back (trace back) to the state 1 of time t+3, the state -1 of time t+2, the state 0 of time t+1, and the state 0 of time t

10   (1→-1→1→0→0). Therefore, judgment of the state '0' at time t is made. Similarly, in a case of time t+5 that is omitted in the diagram, a minimum path metric of a path leading to each state is obtained and four paths are traced back from this state. Therefore, judgment of the state of time t+1 is made.

15   In this case, the number of paths (time) that are traced back is four. However, any desirable number of paths can be set according to the processing speed and the capacity of error correction. As the time of tracing back (going back) is made longer, there is an increase in the memory that stores the past states and the processing time, whereas

20   the capacity of error correction increases.

The constraint on the state transition during the maximum likelihood judgment by the maximum likelihood judgment processor 5f in Fig. 1 is described while referring to Fig. 7 to Fig. 9. As it is shown in Fig. 7(a), when a state transition from a certain time to the subsequent

25   time is taken into consideration, the state transitions from the state 1 to

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the state 1 and from the state -1 to the state -1 are not possible from the differential characters point of view and only a path shown in Fig. 7(a) exists.

When the state transition in three (different) times is taken into 5 consideration, a path 1→0→ -1 that is shown in Fig. 8(a), and a path -1→0→-1 that is shown in Fig. (b) do not exist. Moreover, a path 1→0→0→1 that is shown in Fig. 8 and a path -1→0→0→-1 do not exist as well. This is because these state transitions are not possible from the differential characteristics point of view.

10 Following is the description of a path change that is performed when the maximum likelihood judgment processor 5f in Fig. 1 does not fulfill the constraint. Fig. 10 is an illustration of path change that is performed when the maximum likelihood judgment processor 5f does not fulfill the constraint. As it is shown in Fig. 10, considering the state 15 -1 of time t-1, a path to the state 0 from time t does not exist. Moreover, from the state 0 of time t, a path to the state -1 of time t+1 can exist (can be considered). This path is deleted according to the rule, since the path -1→0→-1 is formed as explained earlier.

However, the possibility that leaving of only the state -1 at time 20 t-1 is wrong, cannot be denied. Because, a case in which the amplitude of the module point of time t has become closer to -1 rather than to 0 that is the actual amplitude can also be considered. Therefore, for this case, a path from the state 0 of time t-1 to the state 0 of time t can also be left.

25 Following is the description of an example of a result of

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ternarizing by the maximum likelihood judgment processor 5f that is

shown in Fig. 1.   Fig. 11 is an example of a result of ternarizing by the

maximum likelihood judgment processor 5f in Fig. 1.

When a module point of a waveform of an edge that is shown in

5   Fig. 11(a) is input, if ternary slicing is performed with 0.5 as a threshold

value, the result obtained is as shown in Fig. 11(b).   Whereas, when

the ternarizing (ternary processing) by the maximum likelihood

judgment processor 5f in the present invention is performed, the result

obtained is as shown in Fig. 11(c).

10   When the module points that are circled in the diagram (graph)

are compared, by making the maximum likelihood judgment with a

broader view, the part that is misjudged by the local ternary slicing can

be corrected properly.

Thus, in this embodiment, the extractor 5a extracts a part that is

15   apparently a bar-code signal from the signal that is subjected to

opto-electric conversion.   The narrow-band differential processor 5b

forms the waveform of the edge by differentiating by using the module

frequency.   The module-point extractor 5d extracts the module point

from the waveform.   The maximum likelihood judgment processor 5f is

20   configured to perform ternarizing based on a maximum likelihood

method by using broader information.   Therefore, the maximum

likelihood judgment processor 5f makes an efficient and accurate

judgment of whether each of the module point is an edge that changes

from a black bar to a white bar, or an edge that changes from a white

25   bar to black bar, or a no edge area.

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In this embodiment, the squared error is provided as reference '1' of the state 1, reference '0' of the state 0, and reference '-1' of the state -1. However, the value of reference is not restricted to these values and a change corresponding to thick black bar can also be made.

5   Describing this further, when the bar code 1 is copied and in cases of a thick black bar and a thick white bar, the amplitude becomes small due to the effect of the beam diameter. Therefore, when a thick black bar or a thick white bar is judged from the dislocation of a module position or the module frequency, an adaptive change can be made like making

10   the reference of the state 1 as '0.75'.

Moreover, in this embodiment, a case of using an optical system that irradiates a bar code by a light beam to acquire reflected light is described. However, the present invention is not restricted to this case only and can also be applied similarly for a case of using an optical

15   system in which extraneous light such as a CCD (charged coupled device) is used.

Furthermore, while realizing the bar-code reader by a program, each section (processor) in the reading processor 5 that is shown in Fig. 1 may be stored in a ROM as a program and each program may be

20   executed by a CPU.

As explained above, according to the bar-code reader of the present invention, amplitude of each module point of the edge data is acquired based on the module frequency of the edge data. Then the acquired amplitude of the module point is ternarized by a maximum

25   likelihood method by using the amplitudes of the module point and a

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plurality of module points that are in continuity with it.   This enables to

make an efficient and accurate judgment of whether each module point

is an edge that changes from a black bar to a white bar, or an edge that

changes from a white bar to a black bar, or a no edge area.

5   Moreover, according to the bar-code reader of the present

invention, a state 1, a state 0, and a state -1 having a predetermined

reference value is assigned to a plurality of module points respectively.

Further, a path that connects all the module points is assigned with a

least squared error of the amplitude of a module that is to be linked and

10   the reference respectively, as a path metric.   A path for which the sum

of path metrics that have undergone the predetermined number of paths

becomes the least (minimum), is considered as a survival path.   The

state of a module point that is at the origin of the path linkage of the

survival path is ternarized as a value of the module point.   This

15   enables to perform the maximum likelihood method efficiently.

Furthermore, according to the bar-code reader of the present

invention, a path from the state 1 to the state 1 and a path from the

state -1 to the state -1 are inhibited.   This enables to reduce subjected

paths based on differential characteristics, thereby performing the

20   process efficiently.

Moreover, according to the bar-code reader of the present

invention, a path from the state 1 to the state 1 via desired number of

states 0 and a path from the state -1 to the state -1 via desired number

of states 0 are inhibited.   This enables to reduce subjected paths

25   based on differential characteristics, thereby performing the process

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efficiently.

Furthermore, according to the bar-code reader of the present invention, when there exists a path from the state 1 to the state 0 or a path from the state -1 to the state 0, a path from the state 0 to the state 0 is left. This enables to prevent the decline in accuracy due to a pass error.

Although the invention has been described with respect to a specific embodiment for a complete and clear disclosure, the appended claims are not to be thus limited but are to be construed as embodying all modifications and alternative constructions that may occur to one skilled in the art which fairly fall within the basic teaching herein set forth.